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Dynamics of innovation in PDVSA and the creation of the Oil Studies University (UVH) in Venezuela

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Author's Declaration:

I hereby declare that I am the sole author of this Master Thesis and it has not been presented to any other university for examination.

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The Master Thesis meets the established requirements.

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Abstract:

This thesis analyzes the evolution of the oil sector innovation system in Venezuela since its emergence until the most recent event – the creation of the first oil studies university in the country, the UVH, by the Venezuelan oil corporation PDVSA. The analytical framework combines the concepts of emerging (national) systems of innovation, sectoral systems of innovation and the multi-level approach to institutional analysis of innovation systems. The paper shows that Venezuela's NSI has had very few changes since the creation of PDVSA and this has hindered the evolution of innovation processes. Most importantly, the oil sector has grown more and more detached from the academic sector. A lack of specialized personnel and fluctuating oil prices pushed the innovation needs towards creating the UVH. However, the rest of Venezuela's science and technology network was not integrated into this project and this affected the institutional logic of the creation and emergence of UVH. Thus, this paper argues that because of path dependencies, a lack of links between the Venezuelan science and technology institutions, the academia and the oil corporation itself, the UVH has ended up becoming a technical training center detached from other universities and with limited impact on the innovation process on the level of the system of innovation.

Key Words: National systems of innovation, sectoral systems of innovation, link building process, levels of institutional analysis.

Index

1. Introduction

Venezuela's main economic engine have been oil related activities. Concessions made way to a nationalization period with the creation of Venezuela's oil corporation, PDVSA, as one of the best oil corporations in the world (Pezzella 2003); however, internal mismanagements, political changes and a lack of specialized personnel affected the company's internal structure and consequently the country's innovation scheme.

PDVSA's R&D center is Intevep, a scientific facility focused on petrochemical studies, supporting all the stages of the oil extraction process. However, since its beginnings and until 2003, it destined less than 8% of its annual budget to R&D activities (PDVSA 2012: 32), the remaining budget was used for supporting oil extraction activities but without a strict focus on innovation and knowledge network. Throughout its history, Intevep managed to develop various innovations such as orimulsion -*liquid coal* process- and over 260 technology developments; however, many of them were eventually dropped because of technical issues and high costs in the production process (Boué 2012: 12-13).

Nowadays, despite the financial support given to R&D in the country (2.69% of the annual GDP) (*Pdvsa aumenta número de empleados, pero no producción* 2013), Intevep has drastically reduced its scientific developments during the last 15 years, partly due to a lack of network development between PDVSA, the universities and other scientific/research centers in the country.

This thesis aims to prove that the actors involved in the Venezuelan innovation system didn't manage to integrate and reconfigure their "internal and external organizational skills, resources, and functional competences towards a changing environment" (Teece and Pisano 1994). As for the the Venezuelan innovation system, it didn't manage to reach a stage of maturity, carrying weak links between the academia, state companies and the private sector, becoming even more constrained throughout the years by the following issues:

- A single political party controlling almost the entire parliament and most political decisions in the government,
- Politicalization of the oil corporation,
- A growing diaspora between the public and private spheres, with the latter being constantly threatened by the government on the basis of potential expropriations (Cardona 2014),
- Emphasis on oil extraction as the main engine for economic growth, and
- Lack of network development between the education and the productive sectors (Mollis and Nussbaum 2007).

To foster the innovation process, PDVSA and Intevep established the oil studies university in the year 2009 (Universidad Venezolana de los Hidrocarburos or UVH), aiming to improve the technical level required by the industry to cope with its internal production requirements and to foster innovation. Its mission was to improve the education level of the scientists and to support PDVSA's strategic key business competences (PDVSA-Intevep-UVH 2009: 10). However, the UVH holds very weak links with other universities and R&D centers, and it's nowadays focused on solving PDVSA's technical deficiencies rather than expanding its network and developing further innovations.

This thesis studies how the innovation network was fostered in Venezuela before and after the oil industry nationalization, specifically the relationship between PDVSA and the academia, and how path dependencies affected the institutions and the R&D network, making way to the creation of the Venezuelan Oil Studies University (UVH).

The theoretical framework presented in the next section analyzes the creation of innovation systems, how mature systems are formed, how's the network building process among institutions and the different levels of institutional analysis. The framework seeks to relate Lundvall's position on emerging and sectoral systems of innovation (applied to the oil industry), together with Hollingsworth's levels of institutional analysis in order to examine the link building process

and coordination mechanisms in a developing system. These concepts will help analyze the Venezuelan institutional arrangement and how the link building process was fostered between the oil corporation and the academic sector.

The historical framework in the third section combines qualitative and quantitative tools for analyzing the Venezuelan NSI before and after the oil industry nationalization:

- How was the Venezuelan innovation scheme before and after the creation of PDVSA,
- How was the relationship between PDVSA and the academic sector between 1974 and 2002, in terms of projects and inclusion of the oil industry in the national innovation plans,
- The changes PDVSA went through after its largest employee strike in 2003, which left the company short of qualified scientific personnel, and finally
- How innovation needs were projected towards the creation of the UVH.

The fourth and final section of the paper examines the innovation activity within the UVH, its goals and scientific network in the oil industry, how it hasn't managed to foster links with national universities nor with other R&D institutions, due to a lack of integration and coordination mechanisms that have reinforced path dependencies and political lock-ins.

2. Theoretic Framework

This paper focuses on the link building process between institutions in an emerging system of innovation, the building blocks that support sectoral systems of innovation, the levels of institutional analysis for determining how mature a system of innovation is, and how complex is its institutional network. This will help determine whether new institutions are required for fostering innovation in an emerging system, or if there are institutional mismanagements that thwart the adaptation process to new market needs.

The first part centers in the development of systems of innovation and emerging markets, the behavior and links between the actors involved (enterprises, R&D centers, scientific pool and labor inflow, universities, public sector capacities and the financial and political policies taken), and how they all lead to changes in policy capacity, generating path dependencies, affecting the behavior of specific industries and the way they reach a stage of maturity.

Second, the literature on emerging systems of innovation takes into consideration how developing countries may present a large number of institutions with weak inter-sectoral links, altogether with a lack of scientific inflow from universities (Galli and Teubal on Chaminade et al. 2009: 7); additionally, when combined with the levels of institutional analysis, this paper aims to show how these weak links hinder the competencies and the capacity for an organization (like PDVSA) to generate and administer technological changes (Teece and Pisano 1994).

The thesis aims to show how path dependencies led the Venezuelan innovation system to underestimate the interaction between the private, public and the academic spheres, accentuated by a political sphere that thwarted the link building process between the actors involved; furthermore, policies taken decades ago generated long-term impacts and policy trajectories that affected organizational structures and the techno-economic dynamism on the private sector and the state-market interaction.

2.1. Innovation and Systems of Innovation

The concept of innovation has been the center of attention for most countries for the past decades, being "the very essence of the capitalist engine of growth" (Schumpeter on Perez 2013: 84). Since an innovation can either be a new product, service or process, it can be defined as "the implementation/commercialization of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer" (OECD-Eurostat 2005:9).

Innovation can be seen under an evolutionary and institutional economics approach, more related to the "cooperation between various actors supported by an institutional infrastructure" (Isaksen and Nilsson 2011:3), thus, innovation shouldn't be analyzed without taking into consideration the institutional and cultural context (Lundvall on Dahl et al. 2009: 7-8).

However, these actors don't innovate as isolated units; there's a collective process between them: knowledge, technology, networks and institutions, altogether with the education system and agencies act in a heterogenous and dynamic environment (Malerba 2009: 10-20). In order to reach a certain level of technical development, a set of actors and institutions are needed to influence the innovative performance in a sector, e.g. scientists and R&D spending by public and private institutions. The technology and information flow among these actors will define the innovation process, translating inputs into outputs (OECD 1997: 3), also known as Systems of Innovation (SI). SIs can also be defined as the interaction between institutions and how they influence the innovation performance among national firms (Nelson and Rosenberg 1993: 4-5).

A country's economic system can't be separated from the innovation one; its innovation policies must be aligned with its economy, education and institutional arrangement (ibid: 13). One of the main reasons why innovation systems vary from country to country is because companies are embeded in social environments, and their social systems of production will influence its national economic performance (Hollingsworth 2000: 616).

The innovation process varies in each country and on each productive sector, where the links between users and the "on-the-job activity of skilled personnel is quite relevant" (Malerba, 2009: 9). Innovation is induced in a user-producer interaction (including vertical and horizontal interaction with other companies and industries), and will be affected by how public policy fosters R&D with structural interdependency between industries and nations (Lundvall 1998: 359-361).

2.2. National and Sectoral Systems of Innovation

This network and interaction between institutions and organizations was introduced by Freeman as the National System of Innovation or NSI (Pietrobelli and Rabellotti 2009: 214), known as 'the network of institutions in the public and private sectors whose activities and interactions initiate, import, and diffuse new technologies' (Freeman 1987: 1). Countries have developed their own systems of innovation, creating different ministries, institutions and universities needed for fostering knowledge generation; nevertheless, links must be built to foster the collaboration between these actors.

The relationship between firms, public policies, institutions and education centers is crucial for studying the interactive aspects of innovation, as opposed to mainstream economic theory where these actors are studied in a more isolated way (Lundvall 1998: 349). The network development between them will determine the kind of innovation a country will have in a historical point; therefore, a lack of development on any of them will ultimately affect the entire system.

Even though firms might be similar in a productive sector, they're also heterogenous and their technologic innovation will take different forms. This is known as Sectoral Systems of Innovation (SSI), where different agents engage in market and non-market activities for creating, producing and selling sectoral products. Sectoral Systems of Innovation take into consideration the institutions, the processes of communication and institutional interactions, without being static in time nor space (Malerba 2002: 247-249).

Each productive sector will have its own network and institutional arrangement, each one requiring a different support from the government and the institutions, and will be more or less flexible depending on the economic area they're embedded into. Technological innovation and demand pull will affect them in a different way, e.g. the petroleum industry is divided into two streams, depending on which aspect of the oil production process they're focused.

Oil companies have a different technologic scheme depending on which level of the production chain they work[1]:

- *Upstream* or *Exploration and Production level*: they deal with underground and undersea oil, as well as gas search and drilling. It is less connected with other economic sectors or demand fluctuations, featuring more rigid institutions and a defined long-term innovation strategy.
- *Downstream* or *Refining, Distribution and Sales*: Out of the two streams, the downstream is the one more connected with market fluctuations, consumer behavior, and other chemical firms (such as fertilizers, pharmaceuticals, etc...) (Bass 2014; PWC 2013).

Some sectors, such as the oil production one, tend to have a more stable and planned innovation strategy, featuring a direct correlation between innovation and success that is unusual in other sectors. Certainly, the mix of modes of innovation with SSIs will also depend on how the actors and policies fostered or hindered innovation among firms; additionally, the market demand will play an important role in defining which policies are prioritized as well.

However, aside from the demand and investment factors within a sectoral system of innovation, policies and innovation processes will differ between developed and developing nations; the latter refers to those countries in need to "access, master, adapt and improve imported technology"- (Chaminade et al. 2009: 217). Different institutional arrangements and the way

[1] Some authors include a Midstream level, focused on transportation and pipeline systems (PWC 2014); however, and in the case of PDVSA, this midstream activities were included in the company's upstream subsidiaries, i.e. the subsidiaries focused on extraction were also in charge of the transportation.

they mediate each productive sector will generate different SSIs.

In order to understand better the innovation process in a specific productive sector and why they reach a certain development level, one must take into account the building blocks that support it:

- *Knowledge and Technology*: the knowledge base and technological domain needed for the production process of a single product and/or service (Malerba 2009: 24-26),
- *Actors and Networks*: the heterogeneous agents that conform a sector, their relationship and communication, connections and information flow (ibid), and
- *Institutions*: norms, rules, conventions, habits and values, "the rules of the game in a society or [...] the humanly devised constraints that shape human interaction" (North 1990: 3).

All building blocks are relevant in the innovation process, however institutions[2] are the key for economic growth. Institutions shape the incentives of key economic actors within a sector and influence "investments in physical and human capital and technology, and the organization of production" (Robinson et al. 2005: 389).

2.3. Institutions, Levels of Institutional Analysis and Emerging Systems of Innovation

Institutions help coordinate the way economic actors interact with each other, they reduce uncertainty, coordinate the use of knowledge, mediate conflicts and provide incentive schemes (Johnson 1992: 26). Institutions are key in the development of specific combinations for both human capital and organizational capabilities within a country (Gittelman 2006). This brings forth issues such as:

- How to 'create' institutions for promoting link development among firms and education centers? Are new institutions required for fostering innovation? Are the existing ones obsolete or unable to build new links between universities and firms?,
- How to manage financial resources within institutions?, e.g. how to assign budget to

[2] Institutions taken as norms, rules, conventions, habits and values (North 1990)

specific projects and/or universities, salaries for scientists and researchers,

- How to measure institutional performance? How to differentiate between institutional mismanagement from the inability to adapt themselves to new requirements?

The creation of institutions, their management and performance measure will affect the innovation process and the human capital management (Harker and Zenios 2000), as well as the academic community, the research capability of their scientists and the students' preparation towards innovative knowledge production (Mollis and Nussbaum 2007:18).

However, it isn't clear how a country's institutional structure is linked to its style of innovation, meaning there's no specific formula on how institutions foster innovation (Hollingsworth, 2002). Formal and informal institutions establish the rules of the game, and both public and private organizations are the actors of that game (Edquist and Johnson on Dahl et al. 2009: 7); simultaneously, these organizations shape the institutional arrangement (Edquist 2001: 7, 20-22).

When focusing on the institutional arrangement in a sectoral system of innovation (e.g. oil production) it is important to consider the levels of analysis required. When a productive sector becomes the main engine of an economy (as with oil production in Venezuela), its scientific development will also change the country's absorptive capacity (Feinson 2003: 18; Albuquerque 2001). Oil extraction activities need large investments and a more planned innovation strategy than other sectors, since their "process innovation has a dramatic impact on not just the bottom line of individual companies, but also on national economies" (PWC 2013: III).

In order to analyze the relationship, links and performance of institutions and sectoral systems of innovation, Hollingsworth defines 5 different levels of analysis (2002):

- 1st level or *Institutional analysis*: understanding norms, rules and values and how they constrain and shape firms.
- 2nd level or *Institutional Arrangement analysis*: coordination mechanisms such as

markets, networks or associations.

- 3rd level or *Institutional Sector analysis*: how institutions "coalesce into a complex social configuration" (Hollingsworth, 2002), how they're configured and how they lead to a system convergence.
- 4th level or *Organizational analysis*: how organizations converge in relation to the institutional environment.
- 5th level or *Outputs and Performance analysis*: how the mix of different social arrangements, organizations and institutions generate different economic outputs.

These different levels help establish some parameters to determine how institutional change affects the productive sector and which links are fostering growth among the actors and networks involved, especially in emerging markets.

Hollingworth's levels of analysis are practical for analyzing developing countries, since they may present a large number of institutions, science and technology-related ministries, R&D centers and universities, though featuring some (or all) of the following constraints:

- Lack of network development between the productive sector, the government and academia,
- Weak (and sometimes non-existent) links between the education system and the productive sector (CEPAL 2010), and
- Inability to build bridges between the government and the private sector (Ibid).

Due to the abundance of variables, it is difficult to develop a defined System of Innovation that can work on developing countries, although Lundvall conceptualizes *Emerging Systems of Innovation* as a combination of modes of innovation (STI and DUI) in order to enhance the innovation process, i.e. engaging interactive learning among different firms and sectors (Chaminade et al. 2009: 9).

The debate on whether a STI[3] or DUI[4] approach is more suitable will vary depending on the environment the firm is working in, and the way the actors behave and communicate among themselves, networks and institutions that support them. In reality, many firms mix elements from both approaches, in order to foster formal R&D and informal channels between firms, industries and institutions.

Innovation modes and policies will vary from developed to developing countries. The challenges each one faces will vary depending on how mature their innovation systems are. In developing countries both the DUI and STI modes may be feeble, the relationship between formal research institutions, universities, firms and government isn't yet strongly built (known as *emerging innovation systems*), plus links may be missing or might be weak (Chaminade et al. 2009: 7). Some developing countries may be closer to a DUI approach, in need of absorbing and adapting foreign technologies and to build competences. They may present a low competition among actors and users, and even a lack of trust among them. On the other hand, strict STI policies might be problematic on developing countries, since they'd require more in-lab development to pursue "new-to-the-world innovations" (ibid: 3).

This relationship between firms, public policies, institutions and education centers is crucial for studying the interactive aspects of innovation, as opposed to mainstream economic theory where these actors are studied in a more isolated way (Lundvall 1998: 349). The network development between these actors will determine the kind of innovation a country will have in a specific historical point, thus a lack of development on any of them will ultimately affect the entire system. If the links between firms, universities and institutions are not strengthened in the long run, firms will have it more difficult to move towards a STI mode. The institutionalization of the innovation process will help build links between firms and research centers (including universities, R&C centers and independent labs), though most importantly it will help channel

[3] STI or Science, Technology and Innovation mode as the "production and use of codified scientific and technical knowledge" (Jensen et al. 2007: 1).

[4] DUI or Doing, Using and Interacting mode "relies on informal processes of learning and experience-based know-how" (Jensen et al. 2007: 1).

the financial resource allocation.

Lundvall takes the concept of *emerging systems of innovation* for identifying which elements are critical or that are limiting the emergence of a mature system of innovation, where market and non-market mechanisms, stronger links and interactions, firms and learning centers will have a more developed absorptive capacity (Lundvall, 1998), with a special focus on "university-industry linkages become more important for catching up" (Galli and Teubal on Chaminade et al. 2009: 7).

2.4. Link Building Process and Coordination Mechanisms

The actors within a society are a product of their history; they're capable of modifying their reality, but there will remain a series of social, political and economic constraints that will influence their decision making. Though they show degrees of adaptability, they usually continue to evolve within a specific style (Hollingsworth 2002). Radical political or financial changes may have a limited scope if the link building process among firms and universities has not been previously promoted by intermediate organizations.

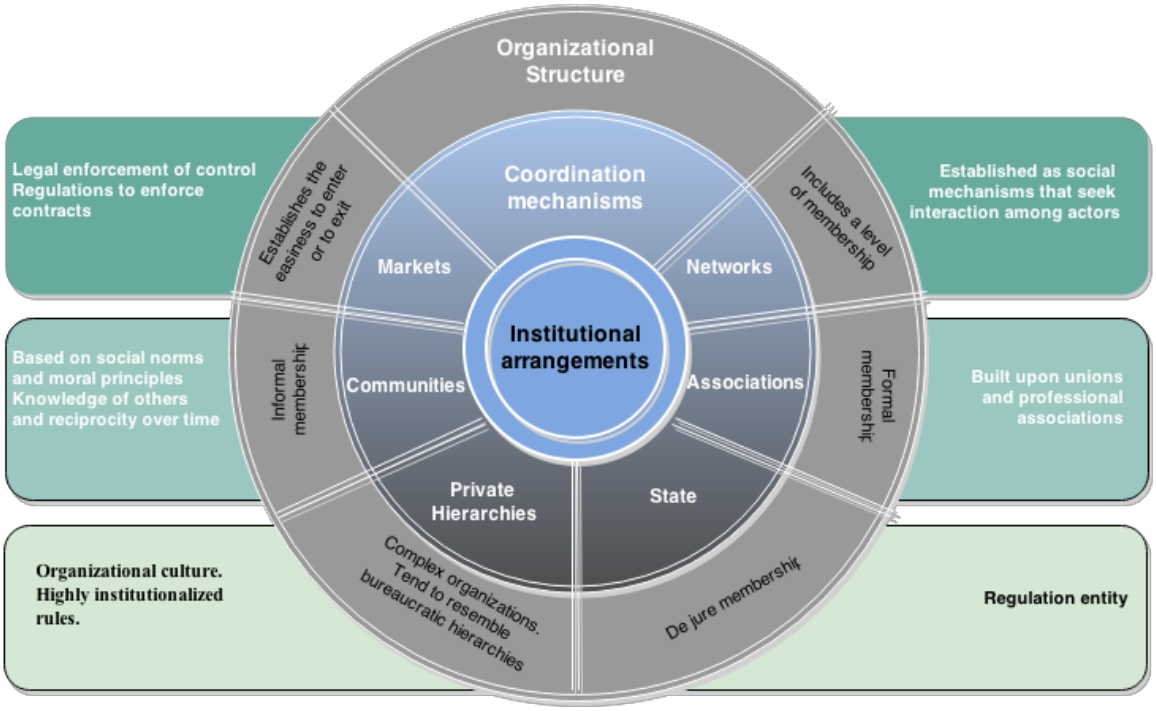
The actors within a sector are therefore influenced by a series of coordination mechanisms that can make them flexible enough to adapt themselves to new requirements or that can constrain them. As Hollingsworth describes, these coordination mechanisms range from markets, communities, networks, associations, private hierarchies all the way up to the State (2002).

Specific institutional arrangements will prevail in certain situations, each one with its own weaknesses and strengths, with its own set of incentives and constraints for its actors. Though these arrangements may create some incoherence in governance (may it be a lack of coordination mechanisms, pattern repetition and/or further strengthening of existing hierarchies), they may also make the system flexible enough to adapt to new requirements.

Public investment is irreplaceable for reaching long-term R&D growth, making the

'Government-University-Firm' relationship crucial for achieving any significant advances and a mature innovation system. Private investments to universities will foster research, though they will be largely focused towards the firms' requirements.

Figure 1: Logics of Institutional Arrangements.



Source: Hollingsworth, 2002

From an educational perspective, these mechanisms will help bridge the research and policy trends, as well as the human capital available with the investments needed to improve a country's research system. These links will help build or expand a country's innovation capacity, enhancing the research productivity, and to make sure that the research is of significant importance and utility (Mollis and Nussbaum 2007: 5-6).

This accumulation of events determine the sector's institutions and creates patterns with specific properties. A country's historical background and its ecosystem will provide a basis for the organizational development, helping build a network and policies that will continue making an echo in the future (Gáspár 2011: 93).

Under this perspective, many developing countries may find themselves stagnated in the technology's assimilation and adaptation process, rather than moving on with a more participative and developing strategy (Dantas and Bell 2011: 1575).

The following section analyzes how the innovation system was developed in Venezuela before and after the oil industry nationalization period, how it didn't strengthen its links with PDVSA and its subsidiaries, and how it didn't succeed in including the academic sector into the innovation scheme. The historical overview also emphasizes how PDVSA grew apart from the Venezuelan system of innovation, and how it built but a few bridges with the academic sector for a brief period of time. The fourth and final section of the paper analyzes the creation of the UVH, how the political circumstances have separated it from the Venezuelan innovation system, and how the weak links with the academic sector have turned the UVH into a training center rather than fostering innovation.

3. Evolution of the Venezuelan Oil Innovation System (1912-2002)

The Venezuelan oil industry has gone through 3 main organizational transitions in the 20th century, mainly:

1. 1912-1973: Concession period. Oil exploitations started as early as the year 1890, but concessions were given out after 1912 when the government signed official agreements with foreign corporations,
2. 1974-2002: Oil industry nationalization. Creation of the first oil-related R&D centers. Economic growth and the creation of a 'State within a State'.
3. 2003 and on: The New PDVSA or "Oil Independence period" (according to the Chavez administration), where the company went through multiple transformations and structural changes, as it will be explained further in this chapter.

3.1. Concession Period

The first period goes from 1912 until 1973 where the first oil concessions were given. This period brought the largest scientific and economic development in the country; however, it's worth mentioning that the Venezuelan oil industry nationalization arrived rather late when compared to nearby countries like Mexico or Brazil, which nationalized their oil industries in 1938 and 1953 respectively (Said Rosales 2014).

Despite the financial growth during this period, the Venezuelan model showed the following constraints:

- Lack of an Innovation System: oil revenues were used to fund different social and economic development projects, though they were mostly focused on financial support rather than building an innovation network (Peña and Flores 2006),

- Lack of integration between the productive sector, R&D centers and education institutions (ibid), and
- Lack of institutional development that would link firms and universities in order to foster innovation (Coronel 2010).

The Venezuelan economic and scientific development has been characterized for its high dependency on technology imports and oil exports. Though statistic data may show a steady growth during the concession period, the relationship between economic growth, technology and education was undermined and did not take a larger size (Calderon et al. 1992: 81).

Starting in 1912, different concessions were given to foreign oil firms, such as the New York and Bermudez Company, Creole, Royal Dutch Shell and Standard Oil (Tinoco Guerra 2010), ranging from 8 to 15% tax on oil revenues, which could have been paid either in money or in goods (Silva Calderón 2006). By 1926 tax revenues from oil activities surpassed that of other economic activities, becoming the main engine for the entire country.

During this period the government's strategy was to use the tax revenues from oil concessions and invest them on improving the national infrastructure and logistics; it also helped creating the first R&D centers such as the Venezuelan Natural Sciences Society -founded in 1931-, and the Experimental Agriculture and Zootechnique Station (Puerta 2008: 224-225). Nevertheless, the government gave plenty of legal freedom to foreign oil corporations, who even participated in the oil extraction legislation issued in 1920[5] (Osorio 2009: 90).

Foreign companies such as the Creole, Royal Dutch Shell and Gulf Oil Co., would continually seek human capital from the Venezuelan universities, transferring this local workforce for training to foreign universities. Since concessions were given for short periods of time (10 to 20 years approx. with variable tax imposition rates), foreign firms didn't have motivations towards

[5] Most concessions were given during the Gómez period, from 1908 until 1935. Juan Vicente Gómez asked these foreign corporations to issue the first law on hydrocarbon extraction in 1920, arguing that: "You know all about oil. You make the laws. We're new in this business" ("Ustedes saben de petróleo. Hagan ustedes las leyes. Nosotros somos novicios en eso") (Betancourt on Osorio 2009: 90).

investing in the Venezuelan education system nor to build stronger links with the universities (Silva Calderón 2006).

3.1.1. Innovation & Technology Adaptation

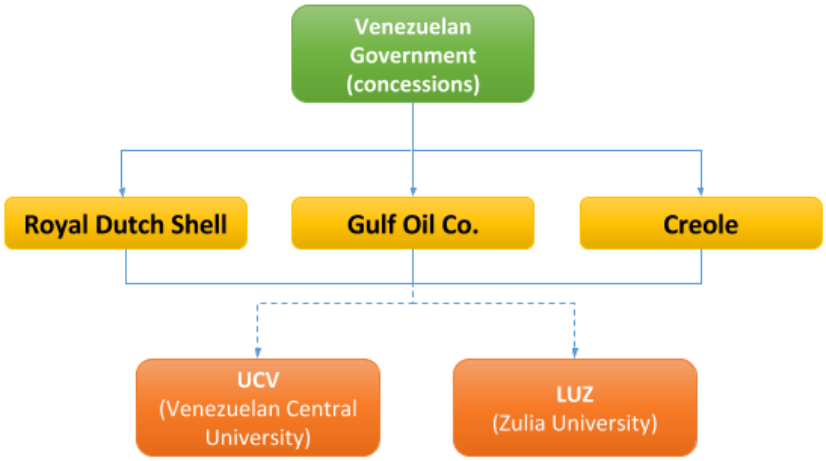
The link between education and the productive sector wasn't directly fostered by any public policy in the country during this period. Since the creation of the Venezuelan Central University back in 1721 until the 20th century, the university education system remained quite strict and excluded from the country's economic reality, i.e. little to no network amidst the university and the productive apparatus (UCV 2013).

One of the first links between universities and the oil industry took place between 1936 and 1958, when universities built direct links with foreign firms working in the oil fields, namely Creole, Dutch Shell and Gulf Oil Co. The downside is that the relationship was informal (no institutional arrangement working as an intermediate, except for having the State as the concessions and financial manager) and it was merely for human resource search, focused on increasing oil production rather than creating knowledge (Núñez and Pagliacci 2007: 17-18).

Some major economic changes took place during the 1939-1943 period, when Venezuela started commercializing oil with the US; the downside was that it gave the US freedom to export any kind of produces to Venezuela with virtually no legal restrictions. Nevertheless, the government managed to create new research institutions with the oil export profits, most of them focused on natural sciences tightly connected with the universities, such as the Natural Sciences Society in 1941 and the Tropical Medicine Institute in 1941 (Puerta 2008: 224-225).

Figure 2 shows the network between the 3 most relevant concessions (Shell, Creole and Gulf Oil) and the universities. The links were rather weak, primarily focused on their need to hire local workforce.

Figure 2: Relationship between foreign oil corporations working in Venezuela and the university sector.



Source: SVIP 2011[6]

It isn't but after 1949, with the end of the dictatorship period, that rapid democratic reforms took place and, as a result of political stability, Venezuela started developing modern scientific research facilities. The government significantly increased its participation in the oil business (from less than 40% all the way up to 66,9% by 1974 and up to 83,9% by 1974) (Núñez and Pagliacci 2007: 7), with an industrialization growth, an import substitution policy, expansion of the education system and further urbanization. The government was focused on pushing other productive industries, given the fact that oil reserves might soon start declining (ibid: 17-18).

It is by 1956 that most countries in Latin America started following the statutes established by the UNESCO concerning planning and mapping research and innovation[7], which in the case of Venezuela ended up with the creation of scientific research institutes that would foster the development of oil research facilities, such as the IVIC (Venezuelan Institute of Scientific Research in 1959), the CVP (Venezuelan Oil Corporation, in charge of administering all petroleum produces and gas distribution by 1960), the Research Center for Experimental

[6] Foreign oil corporations influenced the creation of the oil engineering programs at the UCV and LUZ universities, however they didn't participate directly in the program development in any of them (SVIP 2011)

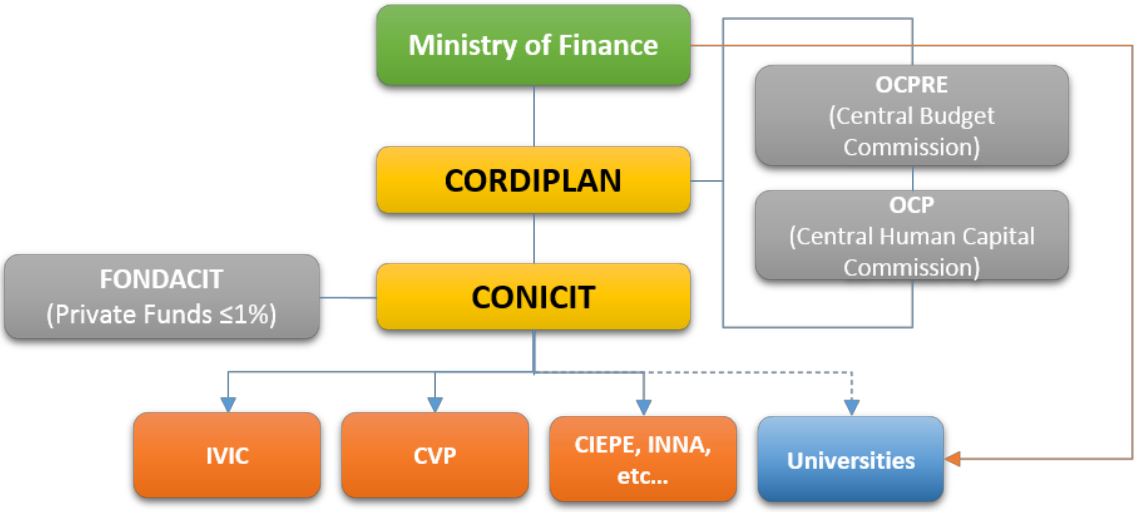
[7] Check the UNESCO's 'Source Book for Science Teaching' issued in 1956.

Agroindustrial Production (CIEPE), and the National Institute for Agricultural Research (INIA) (Calderon et al 1992: 81-83).

From the 1960s, also linked to the UNESCO's influence, the government grew more concerned on institutionalizing the scientific research in order to foster economic and social development. By 1963 the first science and technology data collection started in order to create institutions focused on innovation development such as (Sánchez et al. 2000):

1. **FUNDACITE**, or Fund for Science and Technology Development, in charge of planning, promoting and coordinating local scientific and technologic development.
2. **CORDIPLAN** (Central Office for Planning & Coordination), in charge of formulating and centralizing all development plans, including scientific research. Cordiplan would analyze the sectoral systems of innovation and would develop the national system of innovation. If approved, the project would go through the following instances:
    1. **OCPRE**, or General Budget Commission, in charge of analysing and bestowing the necessary financial resources for each development plan,
    2. **OCP**, or Central Human Capital Commission, in charge of analysing and establishing the required human capital needed to execute the development plans.
3. **CONICIT**, or National Council for Scientific and Technological Research, founded in 1967, served as the main funnel to channel all R&D projects and funds into one single entity. The downside of it was its lack of adequate methodological instrument for keeping up with the public and private sectors' requirements (Test et al. 1999). The Conicit would exclusively receive funds from the Ministry of Finance.
4. **FONDACIT** was an intermediary fund to channel private investments into the CONICIT, 1% of its annual budget (due to the low number of private companies with enough cash flow willing to contribute towards R&D). Aside from the Fondacit , there was no other way for private firms to build a network with the existing scientific research facilities in the country (Puerta 2008: 225-226).

Figure 3: Venezuelan system of innovation by 1970.



Source: Sánchez et al., 2000

By that time the system was efficient enough to link the government, public industries and R&D centers as well as fostering independent research. The Fondacit served as a link builder between private firms and research centers, and also built bridges between universities and the public sector (Sarli 2005: 66-67). The Fondacit's support could come in the shape of project management and scholarships rather than financial funds, since universities would receive direct financial support from the Ministry of Education. This funding and R&D coordination process proved to be successful since its installment, building the very firsts institutional links between public/private firms and universities.

Under this system, the Conicit became the entity in charge of shaping the NSI in the country. Its main contributions can be summarized as follows (De la Vega 2002):

- Created in 1963, it was focused on collecting data on Science and Technology following the UNESCO's «Manual for surveying national scientific and technological potential» (Calderon et al 1992: 82).
- The Conicit made different evaluations about the state of science and technology in Venezuela during 1970, 1973, 1975, 1977, 1983 and 1989.
- By 1983, the Conicit made one of the most relevant science and technology reports in the

country, unfortunately it wasn't taken under consideration by the government for future policy changes.

- The Conicit made the last National Plan of Science and Technology in 1990 (Conicit 1991).
- By 1990 the Conicit continued delivering its reports, though they had a statistic focus instead of developing science and technology plans (Calderon et al 1992).
- After 1998, the Conicit made some radical changes in order to foster the innovation system and developed agendas to involve the different actors and networks (Peña and Flores 2006) which will be described further in this chapter.

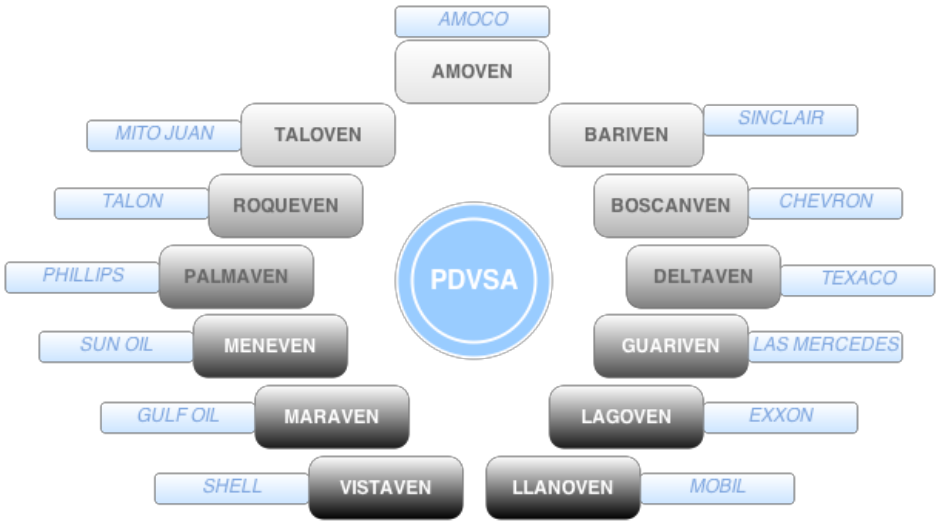
3.2. Oil Industry Nationalization (1974-2002 period)

After 1974, the Venezuelan government nationalized all oil related activities in the country. All concessions were abolished (both foreign and national ones from private investors), and the creation of PDVSA started to take shape.

The nationalization process meant that the organizational cultures from different companies such as Shell, British Petroleum, Exxon, Texaco, among others, had to go through a synergy process. The government decided to keep the same structure that the previous oil firms had kept so far by creating a centralized entity (PDVSA) that would control all the different units (R&D, oil extraction, refinement and delivery) (Suárez-Núñez 2003).

During the 1974-1976 period, the subsidiaries kept the same organizational structure as before, integrating them under PDVSA as a single common unit:

Figure 4: PDVSA's subsidiaries and synergy process.



Source: PDVSA, 2012[8]

However, the first steps after the nationalization process were focused on acquiring foreign technology, as it happened in many developing countries, instead of promoting the national institutions into generating new technologies and/or for improving the ones acquired (LaFuente 2005b). Additionally, the company spent most of its first years unifying the finances, accounts and laboratories, and taking actions on how to commercialize oil barrels and derivatives of petrol to foreign markets (Barberii 1989: IX).

From a technical perspective, it took PDVSA almost 15 years to prepare its workforce (from 1974 until 1990 approx.) and to raise their scientific level to that of foreign oil corporations; furthermore, from 1974 and until the mid 90s, the proven Venezuelan oil reserves were still relatively unknown (Pezzella 2003: II).

By mid 1970s, and due to the high oil prices and demand, PDVSA was focused on catching up with the modern technologies and updating its personnel; it also forced the company to embrace

[8] Since 1960, concessions were given to both foreign corporations, but also to a few Venezuelan entrepreneurs to establish local oil companies, including Mito Juan, Talon and Las Mercedes (SVIP 2011). Once they were absorbed by PDVSA, the goal was to keep the companies' internal structure as intact as possible, but fostering oil production and cooperation among them.

a more profit oriented path, instead of promoting scientific research; hence the scientific knowledge flow towards the economy was distorted due to the profit scheme used by the corporation (Echezurría 1997: 183).

A year before the nationalization process began, the Conicit recommended the creation of an R&D center for the oil corporation, giving birth to Invepet (Calderon et al 1992: 83), developed as a technology transfer institute among PDVSA's subsidiaries (Brossard 1994: 77).

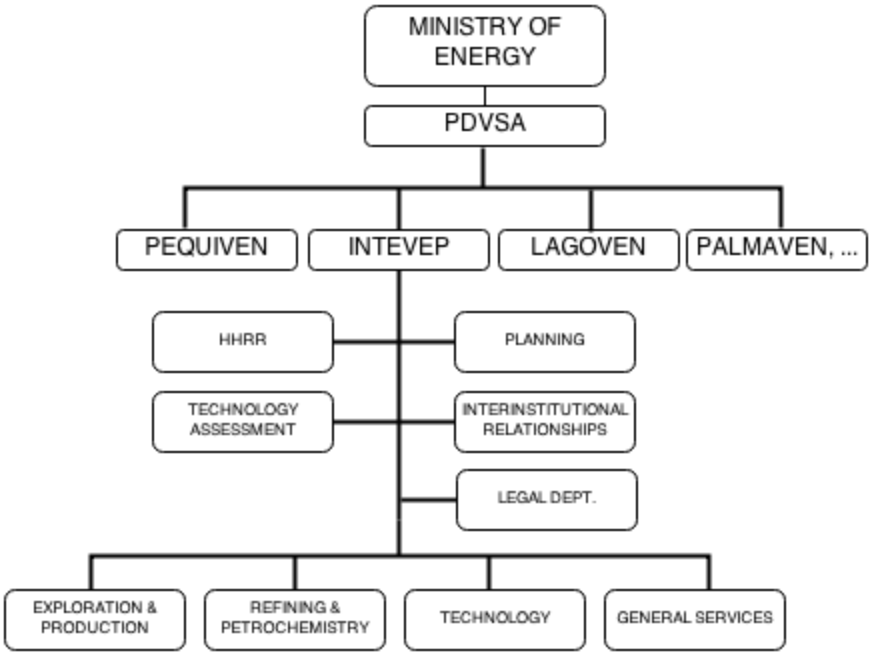
Invepet began operating with 6 technical sub-divisions (Earth Sciences, General Engineering, Petroleum Engineering, Basic Sciences, Process Engineering and IT). By 1978 some 78 research scientists from the IVIC were transferred to Invepet to provide their services for its new departments of Exploration and Production, Refining and Petrochemistry, Administration and General Services (Calderon et al 1992; PDVSA 2014).

By 1979, Invepet changed its name to Intevep (Venezuelan Petroleum Technology Institute), devoted to petrochemical studies and supporting the oil extraction processes.

Since its beginnings, Intevep was focused on satisfying the growing demand for handling crude and extra-crude oil, which represents the majority of the oil reservoirs found on venezuelan soil (almost bitumen-like) (Lopez 2012: 6).

The company kept (more or less) the following structure throughout its first 25 years of existence:

Figure 5: PDVSA's basic organigram from 1979 until 1999.



Source: Espinasa 2006: 147

Despite its growth, the correlation between oil production and GDP kept changing throughout the decades, becoming more unstable after the 1980s when the OPEP put stricter production quotas to its members (see Table 1):

Table 1. GDP and Oil production/refining correlation.

Activity	1968-1979	1980-1989	1990-1997	Average 1968-1997
Crude Oil and Natural Gas	-16,6	48,7	31,1	**15,9**
Oil Refining	32,1	43,3	2,6	**19,4**

Source: Sánchez et al. 2000: 28[9]

Though the relationship between GDP and oil production kept changing continually, it hasn't gone below 30% of the annual GDP since the 80's decade (oil production plus refining).

[9] GDP & Oil production correlation. Data retrieved from Sánchez et al. based on the Venezuelan Central Bank's statistics.

Unfortunately, the company's innovation strategy didn't evolve much compared to its initial years; the lack of policy development towards linking PDVSA with other R&D centers and the academia (aside from the IVIC and a few specific projects with some universities) weakened the education system, which ultimately thwarted PDVSA's knowledge management and innovation performance (Lopez 2012: 8).

It is during this period that PDVSA received the title of a '*State within the State*', since the company controlled the entire oil extraction chain and its commercialization with little to no relationship with other institutions (Rodríguez Araque 2003).

3.2.1. Innovation Process & Technology Adaptation

The first steps after the venezuelan oil nationalization process were focused on:

1. Gathering enough capital to manage the newly established PDVSA,
2. Purchasing foreign technology and training human capital to guarantee the continuity of the operations,
3. Finding markets that would purchase the new Venezuelan oil produces (Silva Calderón 2006).

The government used the previous profits from the concessions to ensure PDVSA's capital (ibid). Acquiring technology and human capital was of extreme urgency to keep the operations afloat; nevertheless, the company focused on acquiring the latest foreign technology instead of fostering national institutions for generating more *ad hoc* technologies and/or for improving the ones acquired (LaFuente 2005b).

Furthermore, being PDVSA mostly an upstream oil company, it required large government investments and had little connection, in terms of innovation, with other economic sectors (PWC 2013).

PDVSA and its subsidiaries didn't join the Venezuelan innovation scheme set during the 1960's,

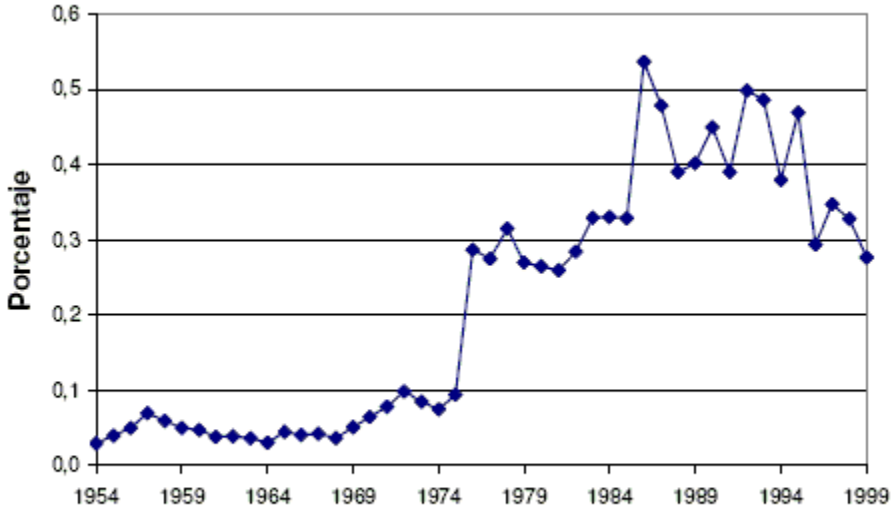
where the Conicit would serve as a link builder in between industries and different R&D sectors. The reasons for it can be summarized as:

1. PDVSA and it subsidiaries worked independently from the national innovation scheme and served mainly as financial supporters.
2. During the 80's and 90's Venezuela, as well as most Latin American economies, had to catch up with the world economy and learn from foreign technologies, focused on "learning objectives that were concerned merely with learning to use and operate technologies" (Dantas and Bell 2011: 1575).
3. Historical factors like the country's fast paced development during the 60's and 70's, and the different types of crude oil found in Venezuela influenced PDVSA's development and growth, i.e. being more focused on keeping up its internal synergy and increasing oil extraction, but without giving further importance to technology adaptation and development (Silva Calderón 2006).

Although PDVSA kept an independent project management and innovation scheme, the Venezuelan government used the profits from oil exports to expand its annual investments on non-oil related scientific research. From 1954 until 1974 the government made an annual investment of 0.21% (on average) of the country's GDP to Science and Technology; after the nationalization period it increased up to 0.39% until 1999 (Requena 2002).

However, and until 2003, PDVSA's annual investment on innovation (within the company) represented less than 8% of its annual budget (most of it used by Intevep), and the remaining funds were used for supporting the oil extraction and refining activities, but without a clear focus on innovation and knowledge network.

Figure 6: Levels of GDP investment to R&D activities in Venezuela (1954-1999).



Source: Requena 2003.

This path can be traced back to the 80's and 90's, when the company's innovations started to grow, especially in Intevep, but many of them were eventually dropped because of technical issues and prices involved in the process (Boué 2012: 12-13).

Aside from a few successful cases, such as the Orimulsión and HHCTM processes (for reducing sulfur content in diesel) (Vessuri 2005a), the number of scientific developments from Intevep started to plunge; hence PDVSA stepped up as the country's cornerstone for its economic relevance, but without pushing forward the scientific network in the country (Coronel 2010).

By 1998 the Conicit started making radical internal changes, reconsidering the scientific research as more interdisciplinary, integrating different actors and resources. A series of agendas were developed to combine social and intellectual capital with the productive sector (Peña and Flores 2006: 36); unfortunately some factors undermined further development, such as increasing project costs, low involvement of non-traditional actors (e.g. independent R&D centers and/or independent university projects), and resource allocation to the same projects (ibid: 42).

Following this path, PDVSA also took some steps during the 90's to expand the network with the universities and R&D institutions: by 1996, PDVSA signed an agreement with the Ministry

of Energy to establish the "University-PDVSA" program to re-activate some oil fields around the country with the help from national universities (Vessuri et al. 2005b: 247)[10]:

- PDVSA and the UCV (Venezuelan Central University), called PetroUCV
- PDVSA and the LUZ (Zulia University), called OleoLUZ.
- PDVSA and the UDO (Eastern University), called PetroUDO

These programs started in 1996, but were discontinued during the Chavez Administration (by 2002 during the oil strike) (SVIP 2011). Although they barely lasted for 5-6 years, these projects represented some of the first steps from PDVSA to integrate the academic world into their productive and R&D cycle.

Some academics blamed PDVSA for not providing them (the universities) with enough financial support and for not keeping the labs and R&D centers technologically updated (Vessuri et al. 2005b: 262), making it difficult for the universities to participate in PDVSA's projects, hence the relationship between the academia and PDVSA didn't grow beyond the agreements above mentioned (SVIP 2011; Vessuri et al. 2005b). One reason behind this is PDVSA's history and previous concession period, creating a private-like vision of its cultural organization:

1. PDVSA trained its own employees, and didn't rely on other institutions or universities for developing technology (except for providing support to PDVSA's subsidiaries) (Silva Calderón 2006),
2. PDVSA was audited by the Ministry of Energy, and didn't have (legally speaking) a direct influence from any other ministry.
3. Though the number of innovation-related institutions continually increased in the country, the different administrations (including Chavez) didn't manage to overcome the lack of institutional coordination mechanisms that would link the different actors and networks within the Venezuelan economy to foster innovation (Hammergren 1999).

[10] PDVSA would keep 51% control of the project, while the universities would keep 49% (Vessuri et al. 2005b: 247)

4. Although PDVSA might have more patents than any other oil corporation in Latin America (such as PETROBRAS and PEMEX), its internal costs and increasing number of employees have made it less competitive; e.g. by 2012 PETROBRAS had a total of 415 patents (Garcia 2012) but holds the highest net income, while the Mexican Institute of Petroleum (IMP) had 711 patents whereas "roughly 25% are still in effect" (*Minister: IMP seeks Closer Ties with Pemex*, 2007); additionally PEMEX has the lowest net income out of the three.

Table 2: Relationship between profits, number of employees and patents registered by PDVSA, PEMEX and PETROBRAS.

Company	Patents registered by 2012	Revenues by 2014 (US$ mm)	Profits 2014 (US$ mm)	# Employees by 2014	World Ranking 2014
PDVSA	1154	$ 120,979	$ 12,933	130,000	41
PEMEX	711	$ 125,943	$ (13,302)	138,215	36
PETROBRAS	415	$ 141,462	$ 11,094	80,497	28

Source: Fortune, 2014; Garcia, 2012

3.3. The New PDVSA: Knowledge Management and Brain drain

PDVSA's relationship with the government tended to be a bit tense during its first 6 years, mostly due to the company's need to reach an internal cohesion and keeping up with the international oil demand; however, it became more balanced after the 80's, when production goals, government incentives, cost reduction policies, internal growth and tax deduction were encompassed between the two forces (government & PDVSA) (Núñez and Pagliacci 2007: 29)

Since the 1980's and until 1999, PDVSA kept a more or less balanced relationship with all

previous governments, until president Hugo Chavez came into power and took socialist measures in the year 2022 (i.e. giving the State more power over the economy), and pushed a 30% tax imposition on foreign oil companies working with PDVSA (Rodríguez Araque 2002: 193). As if that wasn't enough, the government started taking a series of labor policies that favored political sympathizers, especially on a high level hierarchy.

All these measures and further government control over the economy ended up creating the largest and longest employee oil strike ever in Latin America for over 8 months (April 2002 until January 2003) that pursued a political change or Chavez' resignation.

Unfortunately, it all ended up with a massive destitution of the current labor force in the industry (official figures show 18,400 employees were dismissed, 47% of the company's workforce) (Pernia 2003), which forced PDVSA to start from scratch its entire recruitment process, especially on its highly specialized technical areas, creating the largest R&D gap the country had ever gone through.

The previous pool of scientists (engineers, physicists, chemists, etc…) working for PDVSA and its subsidiaries ended up on the streets and in most cases emigrating to other countries (Coronel 2010).

According to official figures and by the oil corporation itself, the workforce loss can be summarized as:

- PDVSA had approx. 39,354 employees by 2002, out of those 18,400 were laid off after the oil strike, representing 47% of PDVSA's total workforce[11] (Ramirez 2013).
- 5% of those dismissals were executives (specialized scientists who had been working in the oil industry before the nationalization period). In other words, out of 1,230 executives that PDVSA had back then, 60% were laid off.
- Approx. 50% of PDVSA's professional oil-related workforce (engineers, scientists, etc..) were laid off (Pernia 2003).

[11] The official figure varies depending on the source, even among official ones, although according to some journalists this number increases up to 23,000 employees laid off (Ramirez 2013; Pernia 2003)

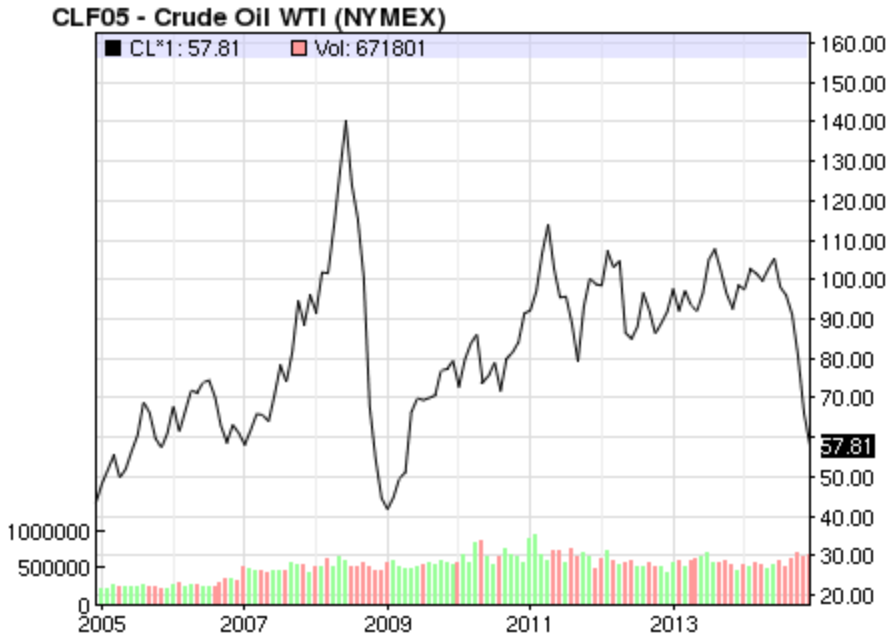
- Almost half of PDVSA's oil-well technicians were also dismissed (ibid).

After the scientific void the oil strike left, PDVSA had to recruit a new pool of scientists, hence raising the need to train them and meet the growing global demand for oil. With increasing oil prices up to US$140 p/barrel by 2008 (Energy Information Administration 2014), the company continued its scheme of training employees abroad (at least for awhile).

In the past when PDVSA was established, the entire oil industry had approx. 800 employees; by by 2012 that number had increased up to 130.000 people (approx. 110.000 directly hired by the industry, and some 15.000 through subcontractors) (*Pdvsa aumenta número de empleados, pero no producción* 2013; Camacho 2014), making it financially challenging to train more employees abroad.

Nevertheless, and with increasing oil prices after the year 2000, the company pursued further cooperation with foreign universities, instead of restructuring itself to develop further technology and to strengthen the network among Venezuelan universities; e.g. by 2006 PDVSA signed an agreement with the Aberdeen's Robert Gordon University in Scotland, and sent some 600 employees to study oil and gas engineering (*PDVSA y universidad escocesa suscriben acuerdo de capacitación* 2006).

Figure 7: Oil price fluctuation between 1970 and 2014.



Source: NASDAQ, 2014

3.3.1. Innovation Process & Technology Adaptation

Throughout its history, PDVSA became the main employer of scientists and engineers, hiring almost 90% of all engineers in the country for several years; the pool of scientists and engineers working for PDVSA and its subsidiaries surpassed that of other industries and research institutes in the country (Luchsinger and Peirano 1999), which made it more difficult for other productive sectors to be more competitive.

Even during the 'golden years' of PDVSA and Intevep, Venezuela's public and private sectors were not fully developed in terms of scientific research, and didn't have the necessary scientific and technologic level to integrate the education institutions (Viana 1994: 154-155). This created a lack of coordination between the productive sector and the education system; some venezuelan authors claim different reasons for it, such as:

1. Lack of knowledge on how universities can actually help the productive sector,

2. Long bureaucratic processes for private firms to reach any negotiation with the academic sector (Granell and Parra 1993: 26-27),
3. Rigid academic institutions focused on fostering knowledge, but not linked to the productive sector (except for specific projects) (CEPAL 2010: 86),
4. Firms tended to be unaware of the activities that R&D centers and universities are capable of,
5. There were many university programs that seeked to foster the academic-productive synergy, but they lacked a long-term vision and credibility in a market dominated by foreign technology imports, e.g. the FUNDEI (Fund for Education-Industry) and/or the Knowledge Transfer Unit from the Conicit or the INVEDI (Research Institute for Industrial Development) (Vessuri 1982: 13),
6. Factors like skills, confidentiality agreements and schedules are the primary fears the public and private sectors have had with the academia (Viana 1994: 44).

This relationship between firms and academia is what finally shapes the innovation process (Edquist 2001: 7, 20- 22); however, as in the case of Venezuela, the R&D sphere stayed quite concentrated within a handful of institutions, working as isolated islands with few bridges towards the academic world. As with many countries in Latin America (with the exception of Mexico, Chile, Argentina, Brazil and Uruguay to some degree) the links between the productive sector and the academia have been isolated and/or random events, rather than systematic and persistent efforts (CEPAL, 2010: 85).

The relationship between PDVSA and the academia tended to be limited to a recruitment process, and providing support (financial aid, scholarships and internships) to universities, with the exception of the PetroUCV, OleoLUZ and PetroUDO programs, which were eventually dropped (Vessuri et al. 2005b).

Despite the high oil prices seen after the year 2003, the innovation process within the oil industry wasn't able to compete in international markets; furthermore, Intevep has kept little to no interaction with national universities in terms of improving the education model or providing

further technologic and education support (aside from financial aid). Additionally, the relationship between the private sector, universities and education centers was rather small during the previous administrations, and has virtually disappeared nowadays (Sánchez et al. 2000: 41).

4. Evolution of the Oil Innovation System since the Year 2003

4.1. UVH: Creation and Development

After the oil strike in 2003, PDVSA had to recruit new employees to fill in the void left by the scientists and engineers laid off. By 2012 the company held over 100,000 fixed employees (Tovar 2012), a growth of 97% since 2006. However, oil production didn't show the same rise. By 2003 there was an average of 61.5 oil barrels produced per employee per day, whereas by 2011 that number had already plunged to 25,1 oil barrels per day per employee (ibid), hence the need to increase (and improve) the training required for the newly hired employees to meet the expected technical level. For these reasons PDVSA registered the creation of an oil studies university in 2009, to cope with the growing need to train its employees, reducing its operational costs, developing R&D projects and to foster innovation in critical areas where the company needs it most (Gaceta Oficial #39.239, 2009).

Three years after its legal creation, the Venezuelan Oil Studies University was officially launched. Its mission was to provide an integral, technical and humanistic education capable of forming professionals related to the oil sector on the oil corporation's strategic key business competences (PDVSA-Intevep-UVH, 2009: 10).

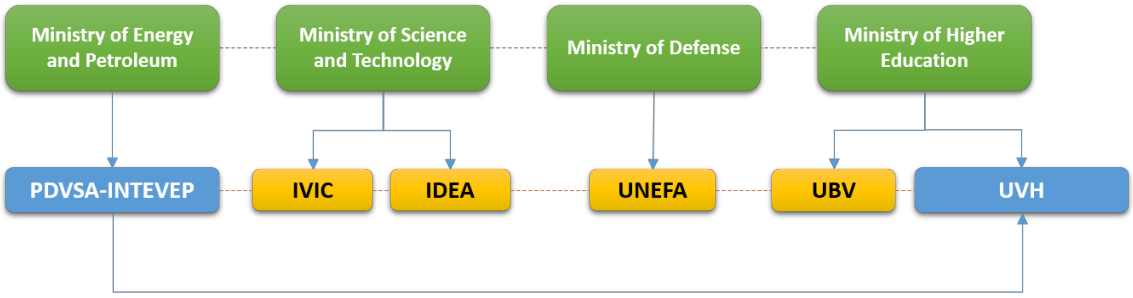
The UVH is legally attached to the Ministry of Higher Education, Science & Technology (as with all universities in Venezuela) and to the Ministry of Energy and Petroleum (Gaceta Oficial #39.239). Financially speaking it would receive (in theory) support from both the Ministry of Higher Education and PDVSA-Intevep. It would be technically managed by Intevep, and it would have its own campus and labs.[12]

[12] The role of the Ministry of Higher Education, Science & Technology is to make sure that the study programs are approved by the National University Council (CNU), and overviewing the legal aspects related to the university administration processes (selection process, grading system, evaluations, degrees) (MPPEU, 2014)

Nevertheless, the UVH is nowadays located inside Intevep's facilities, avoiding costs of building an independent facility, and it is linked to the following institutions:

1. The Venezuelan Scientific Research Center (IVIC),
2. The Bolivarian University (UBV),
3. The National Experimental University of the Armed Forces (UNEFA), and
4. The Fund for Advanced Studies (IDEA), for scientific support on specific projects.

Figure 8: Links between the UVH, ministries and other R&D institutes.



Source: PDVSA-Intevep-UVH 2009

These links were established in the mission and vision of the UVH, but unfortunately there aren't any official agreements signed between them yet. The UVH isn't officially linked to any other research center in the country nor to any other university (aside from the ones aforementioned).

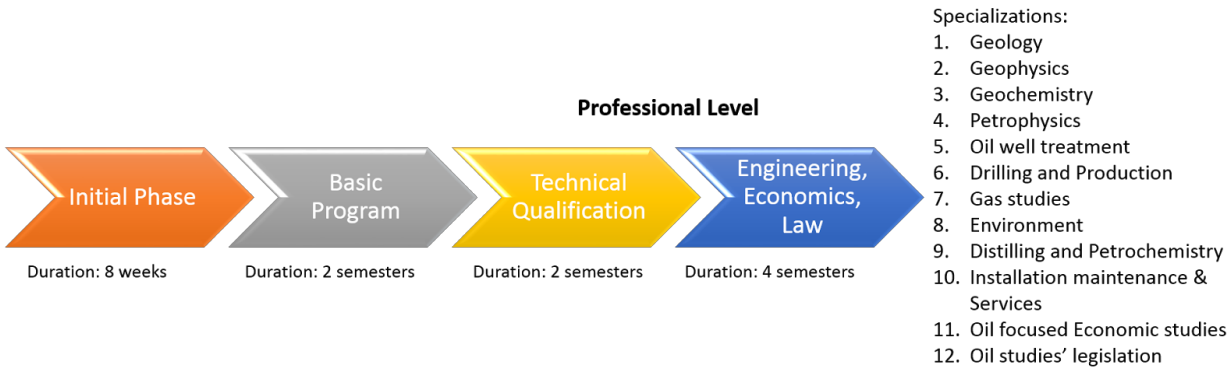
The original study scheme was conceived as a public university that would attract both senior high school graduates, vocational technicians and college graduates; the university would then be flexible enough to provide different levels of specialization depending on the student's preparation, with a specialization relevant enough for the oil industry, in terms of R&D requirements.

4.2. PDVSA and the UVH: Investment & Knowledge Management

During its creation period, the UVH's academic scheme was designed according to PDVSA's production requirements, with 12 specializations that matched the company's milestones on each

productive area: Geology, Geophysics, Geochemistry, Petrophysics, Oil wells treatment, Drilling and Production, Gas Exploration, Environment, Distilling and Petrochemistry, Installation Maintenance & Services, Oil focused Economic studies and Oil studies' legislation (PDVSA-Intevep-UVH 2009: 22-23).

Figure 9: UVH' original study plan (2009).



Source: PDVSA-Intevep-UVH 2009: 6

Although this was the original plan, PDVSA modified it to cover the industry's short-term production goals, such as:

- Increasing the production levels up to 6.000 MMbbl/d (4,000 MMbbl/d from the Orinoco Oil reservoir),
- Increasing the gas production up to 11.947 MMBTU,
- Increasing liquid gas production up to 255 MMbbl,
- Increasing the national distilling process capacity up to 2.2 MMbbl/d,
- Reaching an oil export level of 5,6 MMbbl/d (PDVSA 2012: 31).

The UVH is nowadays running a single master program on 'Oil Reservoir Characterization and Production Monitoring' (not included in the original plan above mentioned), divided into 5 specializations (each one dedicated to a different type of oil found around the country): Orinoco Oil Reservoir, Paria North, Paria Gulf, Travi-Manresa-Orocuai and Framolac (PDVSA-Intevep-UVH 2009: 5-6).

The university designed the master program ahead of the bachelor one, given the urgency to qualify their workforce holding a bachelor degree to increase the oil production and fostering a new generation of highly qualified personnel (Coronel 2010).

However, the production milestones for the 2012-2019 period are higher than in previous years, and PDVSA didn't include the UVH or any R&D project as a main part of their growth strategy, which is shown on their 2012-2019 strategy plan:

Table 3: PDVSA's strategy plan for the 2012-2019 period.

2012	Estimated Budget (millions of US$)	2013	2014	2015	2016	2017	2018	2019	Total 2013-2019
$12,475	Exploration & Production	$16,940	$20,294	$22,998	$28,500	$32,941	$34,095	$33,439	$189,207
$2,682	PDVSA Gas	$1,305	$3,466	$4,438	$4,559	$3,040	$2,730	$2,510	$22,048
$2,094	Distilling	$2,671	$6,344	$5,761	$4,393	$2,942	$1,441	$2,168	$25,720
$715	Commercialization & Supply	$868	$900	$900	$900	$900	$900	$900	$6,268
$6,613	Other Organizations	$3,537	$1,701	$1,701	$1,701	$1,701	$1,701	$1,701	$13,743
$24,579	**Total**	**$25,321**	**$32,705**	**$35,798**	**$40,053**	**$41,524**	**$40,867**	**$40,718**	**$256,986**

Source: PDVSA 2012: 32

According to PDVSA's strategy plan, both Intevep, the UVH and all R&D projects are included under two categories "Exploration & Production" and "Other Organizations" (PDVSA 2012), with virtually no possible way to know how much is actually destined to each one of them. Even though the 'Exploration & Production' level includes some of Intevep's R&D activities, not a single part of PDVSA's report mentions how much money (or budget percentage) is being destined to R&D, much less how much of it is, or will be, destined to the UVH:

- The university budget for 2009 was estimated at Bs. 270,35 mm (approx. US$ 4 mm) (PDVSA-Intevep-UVH 2009: 10),

- This budget was destined to build the university (location, buildings and laboratories) and for administration purposes,
- However, this budget was not officially assigned, and the university ended up being located at Intevep,
- There's no official way to know whether the university budget was included in the 2.69% of Venezuela's GDP for science and technology, or even to know what was the university's official budget after 2009.

As a higher education institution, the UVH would officially receive a part of its budget from the Ministry of Higher Education, but in reality it relies 100% on PDVSA-Intevep; furthermore, its board of directors, rector, vice rector, academic council, labs, and all of UVH's costs are assumed by PDVSA-Intevep.

It is also surprising that the total budget for 'Other Organizations' was actually higher in 2012 than in the following years, going from US$6,613mm in 2012 down to US$ 1,701mm in 2013, which is actually a contradiction given the fact that companies are supposed to expand their investment in R&D to see any significant growth in the long run.

Comparing PDVSA's budget on R&D to other oil corporations in Latin America, we find that:

- PETROBRAS has a policy of investing at least 1% of its annual profits exclusively to R&D activities (PETROBRAS 2012),
- Companies like PEMEX and PDVSA have had an internal policy linked to the political sphere or economic momentum the country might be going through (Soto 2012),
- PETROBRAS' budget for R&D has been on average US$1.5 mm per year during the last 10 years (Duran and Ruiz 2012: 131-132), it substantially increased by 2012 up to US$ 1.1 billion as a part of the company's 2013-2017 Business and Management Plan (PETROBRAS 2012: 3),
- Countries like Venezuela and Mexico have been lagging behind (compared to other oil producing countries) by developing their oil studies universities in the XXI century

(Venezuela in 2009 and Mexico in 2012) (Soto 2012).

- PETROBRAS holds the oldest oil studies university in Latin America (founded in 1966), with 3 different campuses linked to other Brazilian and international universities and institutions (Duran and Ruiz 2012: 132).

Having PDVSA a similar economic performance compared to that of PETROBRAS in terms of profits (PDVSA had US$120,979mm and PETROBRAS had US$141,462mm in 2014) (Fortune 2014), the former has a much lower level of specialists compared to the Brazilian corporation:

- PETROBRAS has approx. 212 PhD scientists, 377 master degree and 306 are university graduates on its R&D Center alone (PETROBRAS 2012).
- PDVSA's entire workforce by 2013 was of 108,365 fixed employees (not subcontracted) out of which only 170 held a PhD degree (PDVSA, 2013: 13).

Unlike PETROBRAS, PDVSA didn't strengthen its inner scientific network and kept relying on foreign institutions to support its know-how. On the other hand, PETROBRAS became a successful case since it managed to break away the 'unidirectional' knowledge flow from suppliers, and its technological accumulation activities grew beyond the assimilation of acquired methods, equipment, services and operational know-how (Dantas and Bell 2011: 1573).

With almost 30% of its workforce holding a bachelor degree, and 19% with a Post-Secondary non-tertiary education degree (PDVSA 2013), the UVH was a necessity that arrived rather late.

4.3. Evolution of the Venezuelan Innovation System (2009-2014)

The functioning scheme of the UVH was meant to fit the production plans and expansion of PDVSA, but in practice it has been limited to helping solve technical aspects required to cover the company's minimum production quota. The UVH isn't working towards creating a professional workforce with a strong scientific background to foster scientific innovation, nor to reduce the company's internal production costs.

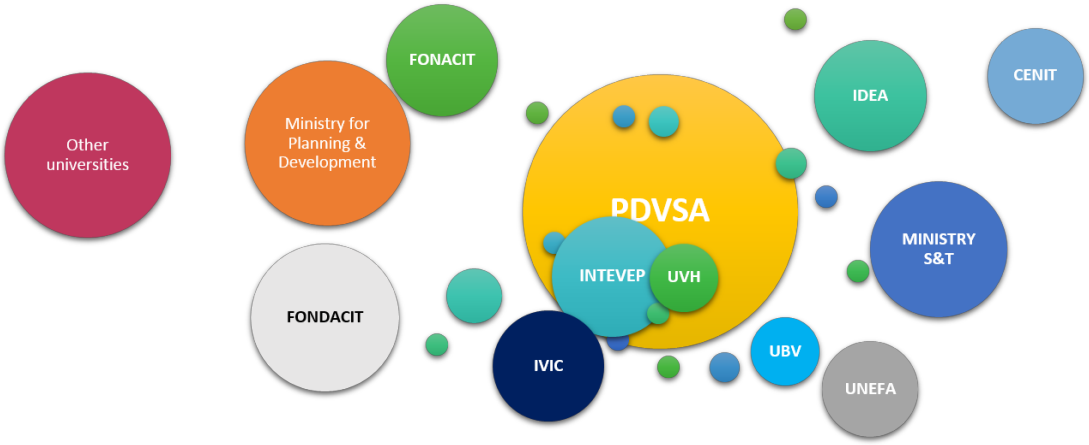
Though the Venezuelan GDP was US$438.28 billion by 2013 with 2.69% destined to Science and Technology (*Pdvsa aumenta número de empleados, pero no producción* 2013) (Cardona 2014), PDVSA has barely some 170 employees holding a PhD degree (PDVSA 2013: 13); thus, the country's R&D investments aren't effectively turning into scientific growth.

The lack of coordination between R&D investments and the actors involved in the innovation process continues to thwart the country's scientific knowledge development. Nowadays Venezuela counts with a large number of ministries and science-related institutions, though with weak links between each other and with the productive sector, including:

- A Ministry of Science and Technology (MCTI),
- Ministry for Planning and Development (MPPP),
- Ministry of Education (ME), divided into: Vice Ministry of Education, Vice Ministry of Primary Education, Vice Ministry of Middle School Education, Vice Ministry of Logistics and Installations and the Vice Ministry for Education Communities,
- Ministry for University Studies, Science and Technology (MPPEU). divided into: Vice Ministry for University Education, Vice Ministry Bureau for Research and Knowledge Application, and finally a Vice Ministry Bureau for Institutional Support, Connectivity and Knowledge Exchange.
- The National Council for Scientific and Technological Research (CONICIT)
- The Fund for Science and Technology Development (FUNDACITE),
- The National Fund for Science, Technology and Innovation (FONACIT),
- The National Center for Chemical Technology (CNTQ),
- The Fund for Advanced Studies (IDEA),
- The National Observatory for Science, Technology and Innovation (ONCTI)

However, the majority of these institutes and R&D Centers have weak links with the education system and tend to work as isolated islands, sometimes unrelated to the universities. The UVH seems to follow the same pattern.

Figure 10: Links between the UVH, the academic sector and other R&D related institutes.



Source: PDVSA-Intevep-UVH, 2009; MPPEU, 2013

Venezuela's institutional arrangement is nowadays partly based on previous scientific reports made by the Conicit, which have been added to the Venezuelan National Plan for Science, Technology and Innovation 2005-2030. This system follows a neoclassical innovation perspective, expecting a quasi linear relationship between R&D and growth, i.e. overemphasizing economic support on R&D and expecting innovation as a result (Chaminade et al. 2009: 4), undermining the relationship between public and private sectors with the education system and R&D centers, altogether with a lack of feedback and learning process, as well as hindering the relationship with foreign institutions.

In the case of Venezuela, some of the problems related to the system of innovation are:

- "The competences and capabilities of the organizations of the system,
- The institutional frameworks, and
- The interactions among organizational actors" (Chaminade et al. 2009: 5).

These problems are present in the Venezuelan institutional arrangement and functioning, and the country's large number of institutions and ministries supporting the national system of

innovation haven't translated into innovation. This is also perceived in the Venezuelan innovation plans, which were linked to the development of the Conicit, with the following inconsistencies:

- Methodological problems in the data gathered,
- Lack of methodology for turning statistical data into indicators and steps for fostering innovation,
- Lack of management within the Conicit,
- Lack of government support towards the Conicit (financial support and for implementing its recommendations),
- A decline on the Conicit's reports during the 90's, since they became more focused on statistic data (De la Vega 2002).

Not only was the participation of the Conicit lower by the end of 80's decade in terms of project management, policy development, scientific support and recommendations, but the financial support towards scientific development inside the universities was also diminished (both from the private and public sectors) (De la Vega 2002).

Following Hollingsworth's 1st, 2nd and 3rd level of institutional analysis (institutions, institutional arrangements and the institutional sectors of a society, respectively) (2002) Venezuela has been characterized during the past 15 years by:

- A constant creation of new institutions, within the science and technology sector,
- Growing government investments, without a clear institutional, science and technology agenda, and
- Lack of cohesion and coordination between different sectors (public, private, R&D and education) in order to foster development.

As pointed out by Lundvall (1998) and Hollingsworth (2002), the tripartite 'Government-University-Firm' relationship is of crucial importance for a developing system of innovation to become mature.

Following Malerba's building blocks that support the innovation process (Malerba 2009: 24-26), the institutional arrangements in Venezuela already started to decline since the mid 70s, due to a lack of network between institutions, and a growing isolation of the education system from the productive sector, especially between the universities and PDVSA. Even though the number of institutions involved in the science and technology sphere has considerably increased since 1999, the lack of coordination mechanisms and integration of the productive sector with the academia have made the innovation system languish and not reach a mature level as a basis for the country's development (Cardona 2014).

Taking into consideration the fourth level of institutional analysis, the lack of internal organization within the ministries affected the way R&D has been fostered in the country (Hollingsworth 2002). According to an evaluation made by the University of Zulia on the Venezuelan Science and Technology Ministry, describing the lack of internal coordination among departments, specifically between the procurement and project management departments, they found:

- A lack of internal management,
- lack of interdepartmental communication, and
- Continual fund allocation to the same projects and/or institutions, without analyzing the current market situation (Peña and Flores 2006: 44).

The same lack of internal coordination and planning can be found inside PDVSA, and even more when Intevep and the UVH come into play. Although there's a link between the oil industry requirements and the UVH, R&D implementation and monitoring have not been carried out effectively, topped by a lack of defined public policies (ibid).

4.4. Network building: Reality vs. Expectations

A common factor found in several Latin American countries is the percentage of GDP invested in science and technology, a high number of domestic funds and development institutions that

have consequently led to 'diminishing returns' (i.e. a large number of funds and institutes with various goals that generate a schedule difficult to achieve), which should push the governments to reconsider their national priorities (Hammergren 1999).

Back in 1999, the Venezuelan government invested an average of 0.7% of the GDP in science and technology, and in 2005 the Ministry of Science and Technology pushed the government into assigning further financial support to the scientific and technology sectors, claiming that the current investment level was not enough (Ministerio de Ciencia y Tecnología 2005 :71). The investment increased from 0.7% up to 1.74% by 2007, and finally reached 2.69% by 2012, almost 10% of what Latin America invests (in total) to science and technology (Cardona 2014).

Despite this high annual investment, the Ministry of Science and Technology claims that the country doesn't have the necessary qualified human capital to reach a better level of development, as well as a lack of focus towards the smaller communities (Ministerio de Ciencia y Tecnología 2005: 71).

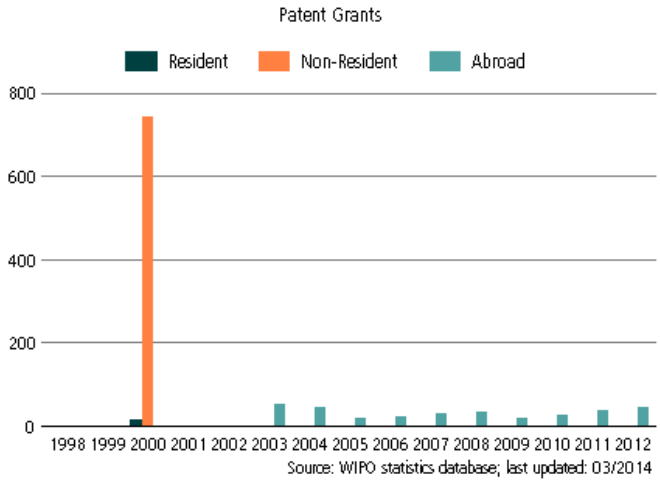
The Venezuelan Science, Technology and Innovation System report for the 2005-2030 period is quite general, doesn't go into specific measures to incentivize cluster creation, and falls short for integrating private-public and academia (the private sector is clearly not taken under consideration). The report isn't focused on enhancing the research productivity between all sectors in the society, nor seeking to ensure the utility and relevance of the research (Mollis and Nussbaum 2007: 6).

It would seem reasonable to think that with an annual investment of 2.69% of the country's GDP in Science and Technology the results should be among the best ones in the world, or at least in Latin America. Unfortunately, and according to the World Bank, Venezuela barely requested 33 patents by 2011 -one more than Haiti- (World Bank 2012)[13].

[13] According to the WIPO, out of those 33 patent applications in 2011 only 14 were actually granted (as patents for residents), since then all patents have been granted abroad (325 patents registered abroad since the year 2003) (WIPO 2014).

In the past, Venezuela produced an annual average of 16 patents, mainly from Intevep and PDVSA (WIPO 2014), and by 2002 the patent generation became virtually null, with a slight recovery after 2003, without any significant activity from the private sector (Requena 2011: 343). After the oil strike, the gap between quality assurance and policy evaluation grew larger, hindering the development of research-oriented universities (Mollis and Nussbaum 2007: 6).

Figure 11: Patents granted to Venezuelan firms, academia and institutes (1998-2012).



Source: WIPO 2014

The patent registration in Venezuela has declined due to the following reasons (Culshaw, 2013):

- In 2006 Venezuela left the Andes Community (CAN) and stopped following the international regulations for granting patents.
- Eduardo Samán, former Ministry of Commerce and former director of the Venezuelan Autonomous Service for Intellectual Property (SAPI), commented that "patents should be granted as concessions" (Culshaw 2013), i.e. controlled by the government.
- Since 2006, the SAPI stopped granting patents to universities and private firms, except for the oil corporation.
- Universities and research centers find more security registering their patents abroad through foreign institutions[14].

[14] Unfortunately the patent situation in Venezuela has undermined the scientific activity in the country,

All these legal changes have negatively affected the scientific development in the country. The little investment that comes from the private sector barely reaches any scientific R&D center and doesn't translate into scientific development, much less into patents (Cardona 2014).

Within this context, the development of the UVH arrived late and amid unfavorable conditions, constant internal changes in the oil industry, and a national economic crisis where the financial investment capacity diminishes by the day. However, the internal requirements of the oil industry to rapidly increase the education level of its workforce are critical to strengthen the exploration and production capabilities.

Some policies can be taken into consideration for improving the PDVSA-academia relationship, such as:

- Pushing PDVSA and Intevep to work together with the different universities around the country that have any oil-related study program (petroleum engineering), e.g. UDO, LUZ, Universidad de Carabobo.
- Taking back the previous PetroUCV, OleoLUZ and PetroUDO programs with the UVH in order to foster network building among universities.
- Supporting these universities (UCV, LUZ and UDO) to update their oil engineering study programs and infrastructure, and link them to PDVSA's scientific requirements (so the gap between what PDVSA needs and the quality of the graduated students doesn't grow larger than it already is).
- Linking the UVH with other universities in the country that also have an oil-related program for sharing projects and scientific research.

On a larger scale, considering the private and public sector with the academia, some recommendations are:

forcing several venezuelan research centers to register their patents abroad, thus making these profits stay in those countries where they were registered (Carmona 2012).

- Encouraging the academia to be more flexible and developing projects that can help satisfy the technological needs the companies may have (Echezurría 1997: 185),
- Fostering further knowledge transfer between institutions, R&D centers and universities, giving importance to the local and foreign market needs (Ruiz 2000: 7),
- Introducing institutional reforms that would help speed the patenting process, and facilitating licensing agreements and technology transfer between universities and the productive sectors (CEPAL 2010: 87-89),
- Going beyond the mere creation of institutions and science-related ministries, but rather consolidating formal and informal knowledge exchange channels so the social agents can take advantage of the information and knowledge flows (Peña and Flores 2006: 44-45),
- Increasing the universities' budget instead of reducing it[15].

Venezuela's 'dutch disease' effects seem to be continually appearing, and the recent protective policies haven't helped solve the problem of allocating resources in different economic areas, especially with a lack of management and links between ministries, public/private sectors and the academia. The problem of downsizing the State in Latin America and liberalizing the economy strengthened path dependencies (Franko 2003: 73) and resulted in a lack of coordination from the actors and network. Nevertheless, issues like the Washington consensus (ca.1989) are difficult to include in this analysis, since these neoclassical policies re-strengthened path dependencies from the mid-70s and 80s that were already present.

Furthermore, the different agendas recommended by the Conicit ran short in their scope and didn't manage to overcome previous constraints (Peña and Flores 2006), and the current policies made by the CNTI (National Center for Information Technologies), the MCTI (Ministry of Science, Technology and Innovation) and the MPPEU (Ministry of University Education, Science and Technology) still follow a neoclassical approach rather than implementing policy coordination and stronger business-Government links (Karo and Kattel 2014: 98), synchronized with the academic sector. It might be useful to integrate concepts of how to overcome political

[15] In 2014, the budget for Venezuela's Central University was estimated at Bs 8,22 milliard (approx. US$ 7 billion), but the government barely approved 40% of it (Bianco 2014),

lock-ins that hinder "renewing and restructuring" (Hassink 2005: 5), since government policies are partially responsible for hindering technological change (Könnölä et al. 2004: 149). However, and until the private and the academic sectors in Venezuela aren't taken into consideration, government policies will be incomplete and lacking coordination.

5. Conclusions

This thesis followed the creation and growth of the Venezuelan oil corporation and its relationship with the country's NSI, arguing that the system remained without major changes for nearly 30 years, and the modifications it went through during the Chavez administration were focused on re-naming the previous ministries and institutes and creating new ones, but with a lack of institutional coordination mechanisms that would link the actors and network to foster the innovation system. Using the levels of institutional analysis, it pointed out the lack of internal management within the Venezuelan Science and Technology Ministry, and continual financial support to the same projects, without fostering different areas of development, nor building tighter links between the actors involved.

The previous Venezuelan NSI established in the 1960s managed to gather together R&D centers and ministries for the first time, and made efforts to include the (small but growing) private sector in the country. After the creation of PDVSA and the establishment of Intevep, the path dependencies reinforced the weak links from the previous NSI, such as failing to integrate the private sector with the universities into common projects and, most importantly, failing to integrate PDVSA into the existing innovation system and improve it.

As with some other Latin American countries, Venezuela's previous NSI integrated (in theory) the different actors involved in the innovation process (R&D centers, universities, government, private and public sectors), however policies were rather general and not specific towards strengthening their relationship in concrete. During the Chavez administration, some of the most relevant flaws in the policy-making arena were:

1. To focus the efforts in creating more science and technology-related ministries and institutes, all with various goals and weak links with each other[16],
2. To exclude the private sector from the innovation system, and
3. To diminish the role of the universities in the innovation process and their relationship with the productive sector.

The lack of long-term project management on the PDVSA-Academia programs has negatively affected further R&D cooperation between universities and the oil corporation; in addition to it, the lack of financial support from PDVSA for improving R&D facilities in the universities have made them lag behind when compared to other international institutions.

Even though the discussion of levels of institutional analysis, emerging and sectoral systems of innovation can help see the big picture on how were the links developed between ministries, public and private firms and the academia in the Venezuelan context, it is also necessary to use additional tools for having a more holistic view on how the different political changes affected the institutional structure, and how would be the implementation process of different innovation policies (or agendas) in a developing system, and how to overcome path dependencies.

The oil sector has become the one and only engine that runs the Venezuelan economy, forcing PDVSA to repeat the cycle of increasing the oil production and not focusing on innovation through Intevep and the UVH, topped up by a lack of network with the rest of the national academic sector. In sum, no policy would be effective if the Venezuelan government continues undermining the role of the academia and the private sector[17], and not seeing a larger development path if the three main forces would work together synchronized (public- private

[16] Nowadays the Venezuelan government has even created a Vice Ministry for the Supreme Social Happiness (Viceministerio para la Suprema Felicidad Social del Pueblo) to follow up the execution of social projects.

[17] Former president Chávez and many of his followers tagged the opposition party and the private sector as *the unpatriotic oligarchy, the sick oligarchy* and/or *dying capitalism* (*oligarquía apátrida, oligarquía enferma* and *capitalismo moribundo* respectively in Spanish), for supposedly creating a series of assassination plots against Chavez (Chávez Frías 2010). There's even a conspiracy theory stating that the opposition party, the private sector and US diplomats were behind the death of former president Hugo Chavez (Golinger 2013).

sectors and the academia).

One challenge for policy-makers in Venezuela is to break away from a strict state-led (communist) model and to engage the private and academic sectors to work altogether in common projects. As discussed in the theoretic framework, another opportunity is to stimulate PDVSA's internal innovation scheme through a DUI-learning form, and link the projects and requirements to the UVH and to other national universities. It is also important to move investments to other productive sectors in the country, not focusing on oil production activities alone, and raising the share of firms and sectors that can contribute to the innovation system. Additionally, the legal framework has to favor the patent registry to the academic and private sectors, so other economic areas can also contribute towards innovation growth. Finally, a reconfiguration of the current ministries and scientific-related institutes is of utmost importance, so their goals can be in sync, reducing bureaucracy and enabling them to link the actors into different projects.

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